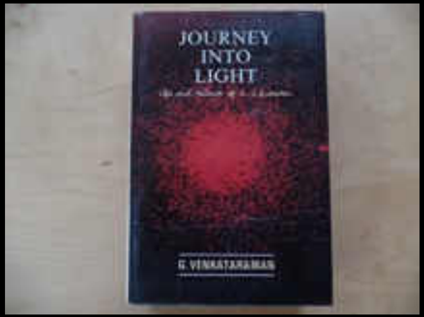
Global science for global well-being

Thalappil Pradeep
Institute Professor
Deepak Parekh Institute Chair Professor
IIT Madras



Global science – why now?

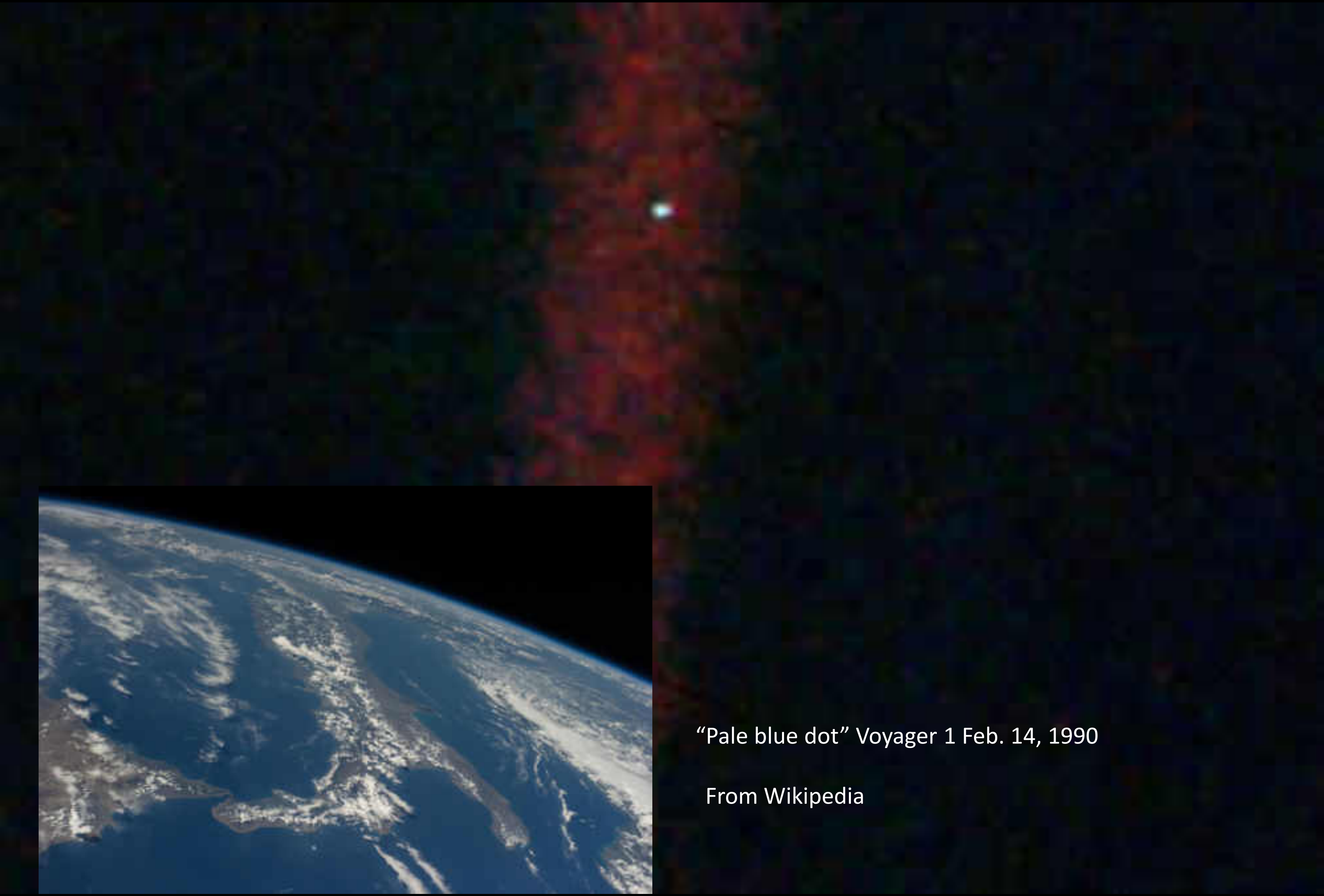
Thank you, Krishnan Narayanan
Nishani Manohar and Papiya Mahapatra
IITMAA

IIT Madras Alumni Association, February 27, 2023

Earthrise

Earthrise, taken on December 24, 1968, by Apollo 8 astronaut William Andres.

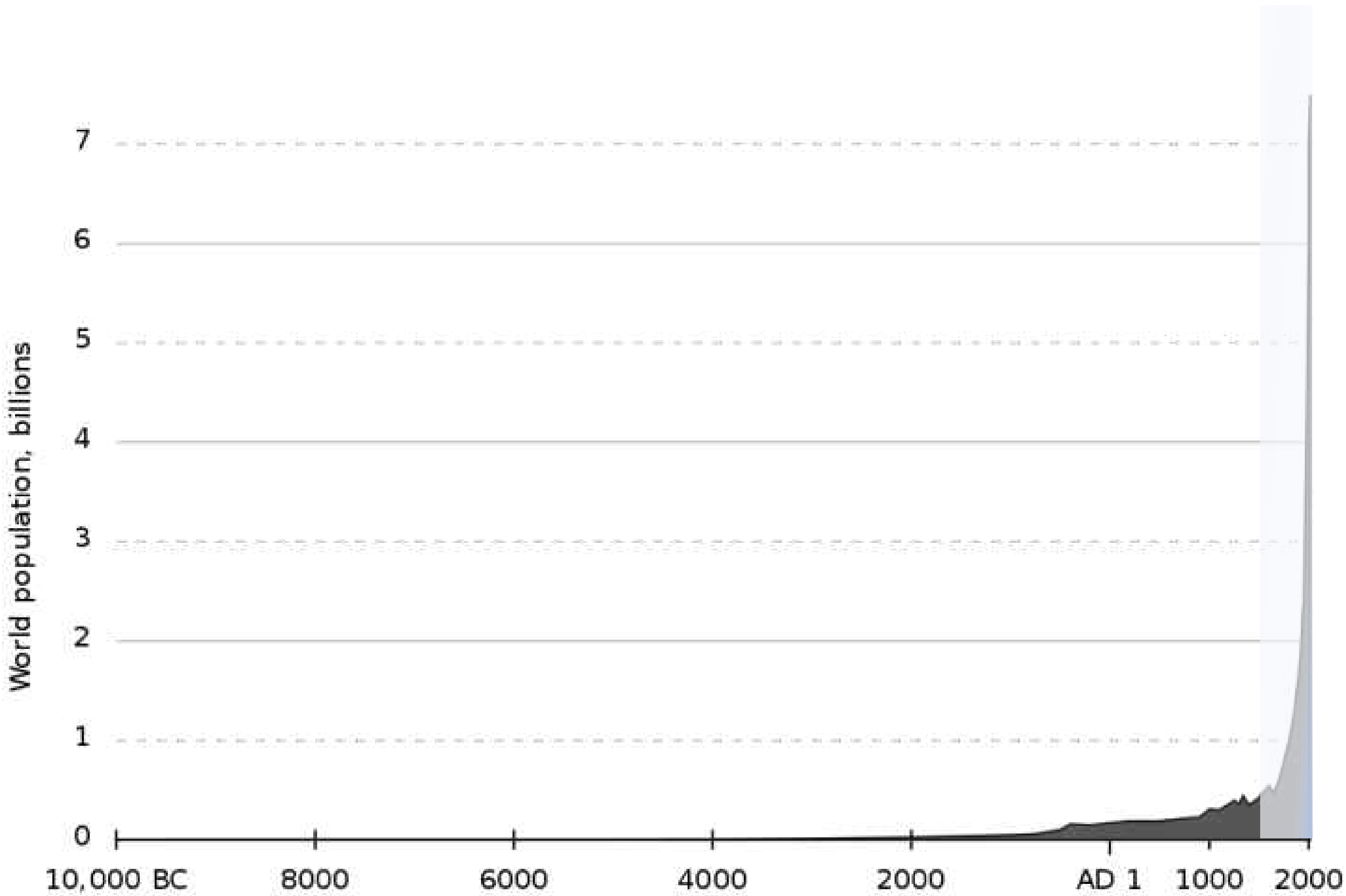
Nature photographer Galen Rowell declared it "the most influential environmental photograph ever taken".



“Pale blue dot” Voyager 1 Feb. 14, 1990

From Wikipedia

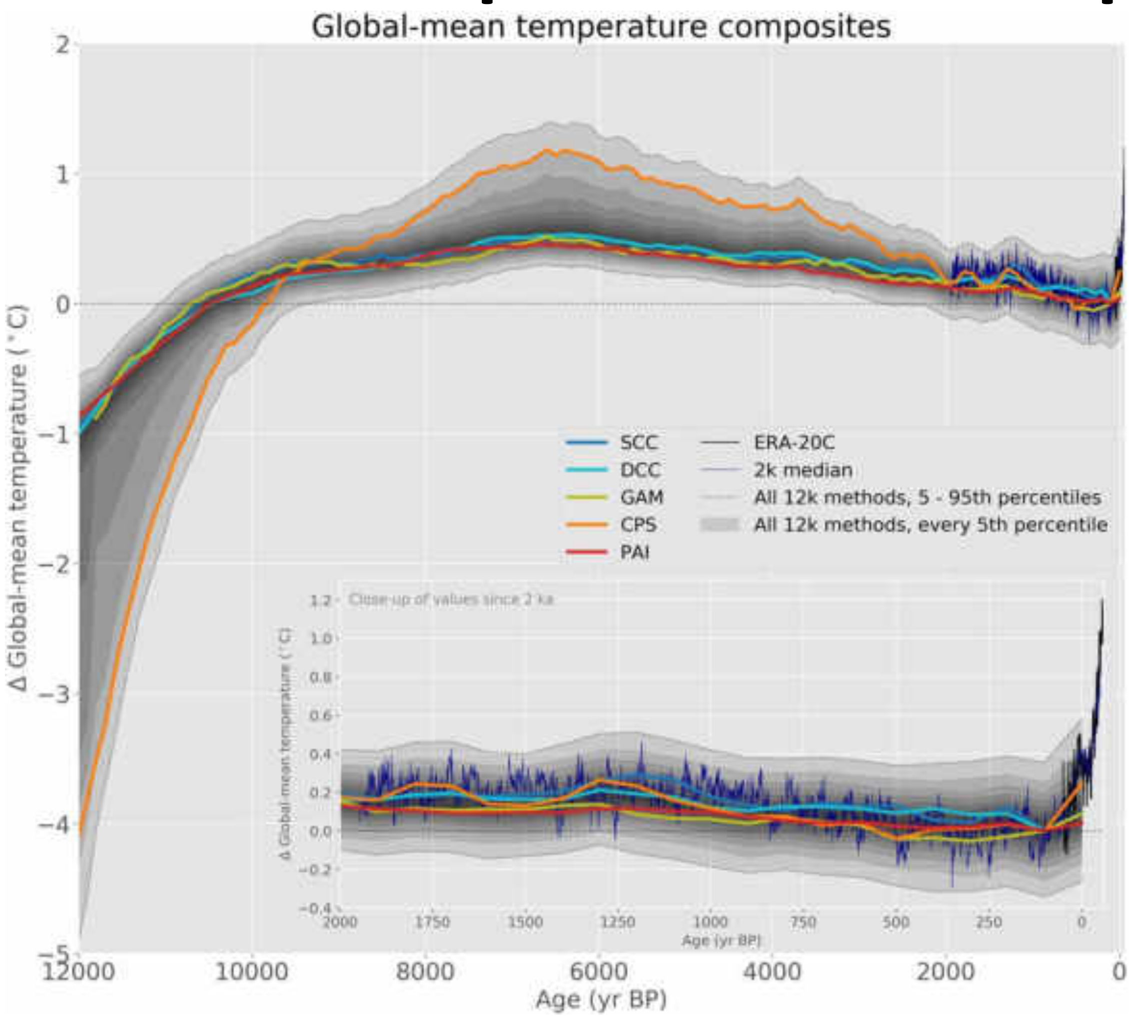
World population



Wikipedia

Galileo Galilei 1589-92

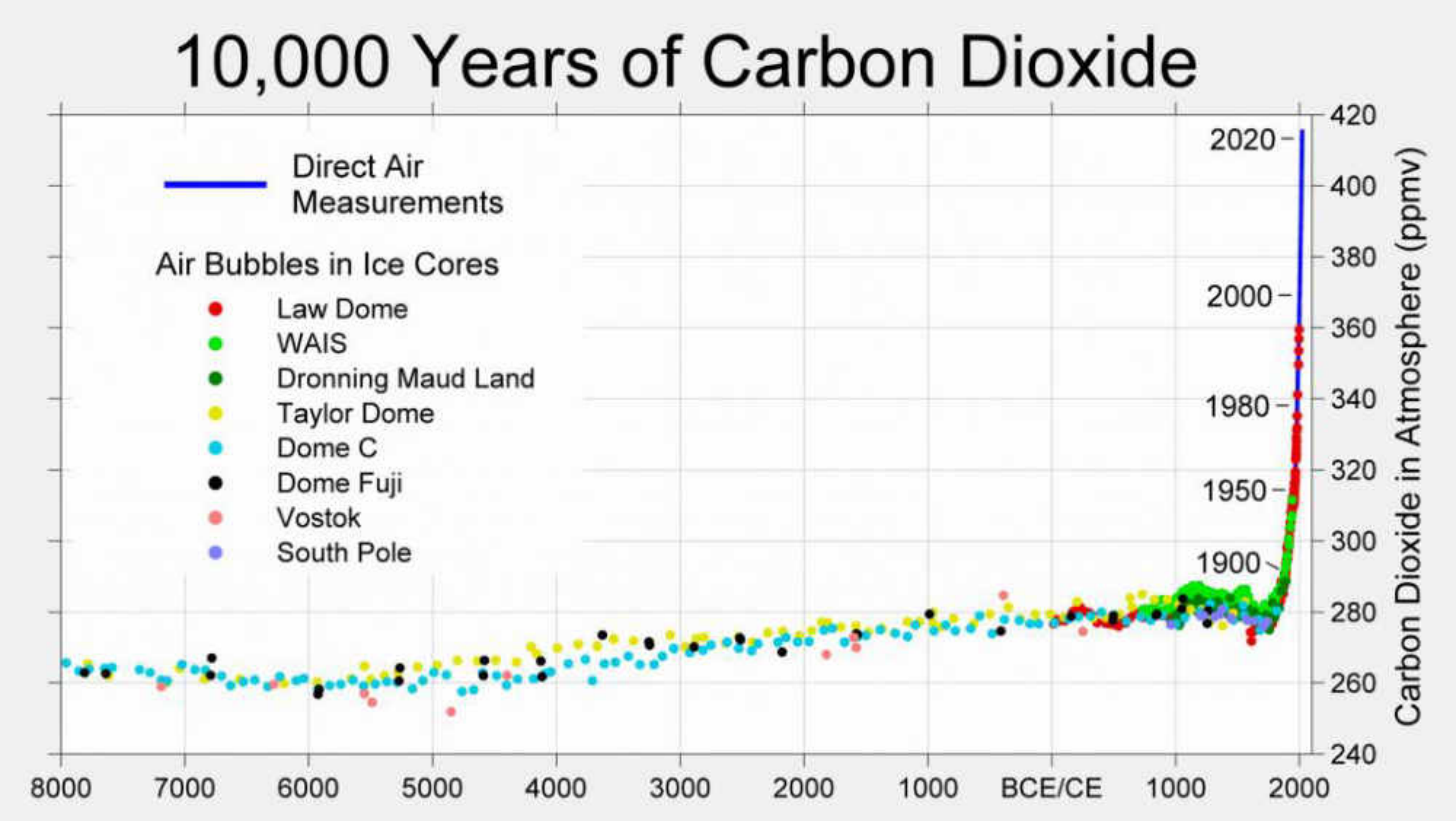
The Holocene Epoch – The triumph of man



Global mean surface temperature from the Temperature 12k database using different reconstruction methods. The black line is instrumental data for 1900–2010 from the ERA-20C reanalysis product. The inset displays an enlarged view of the past 2000 years.

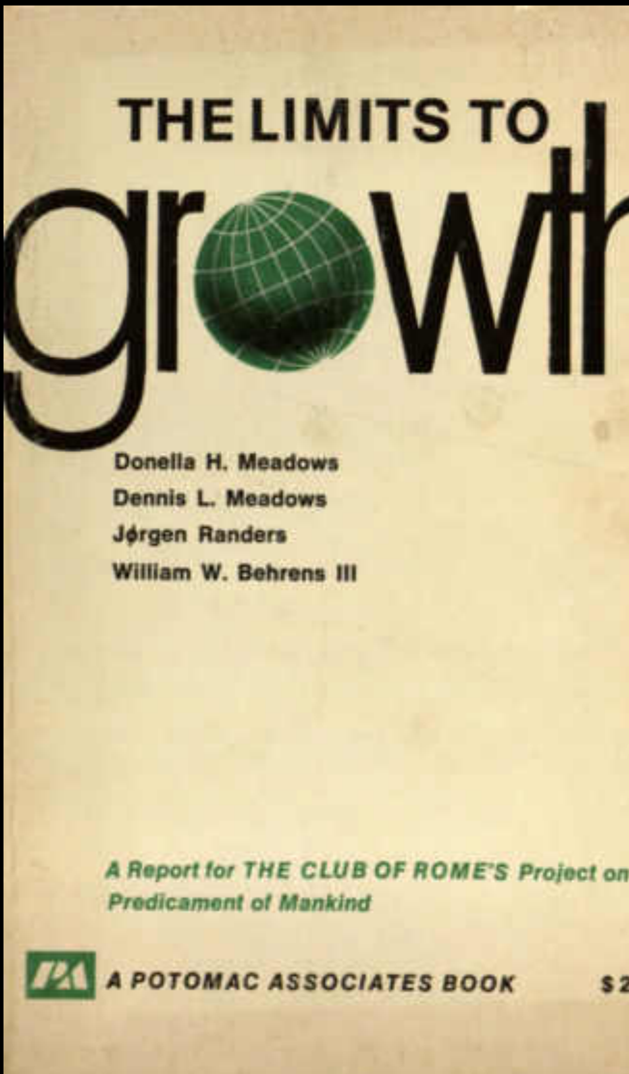
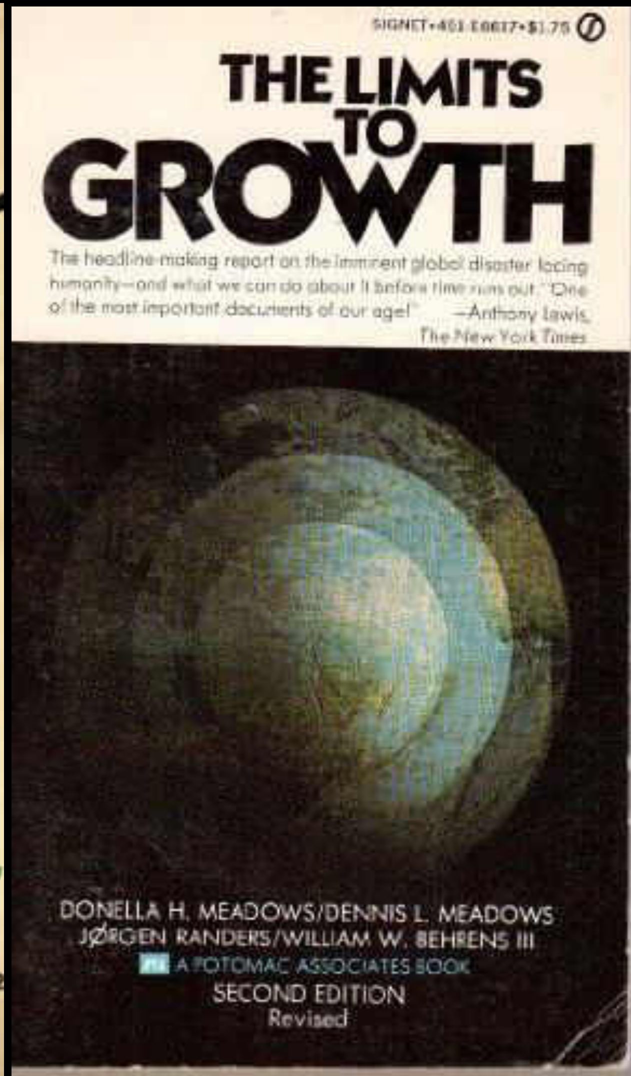
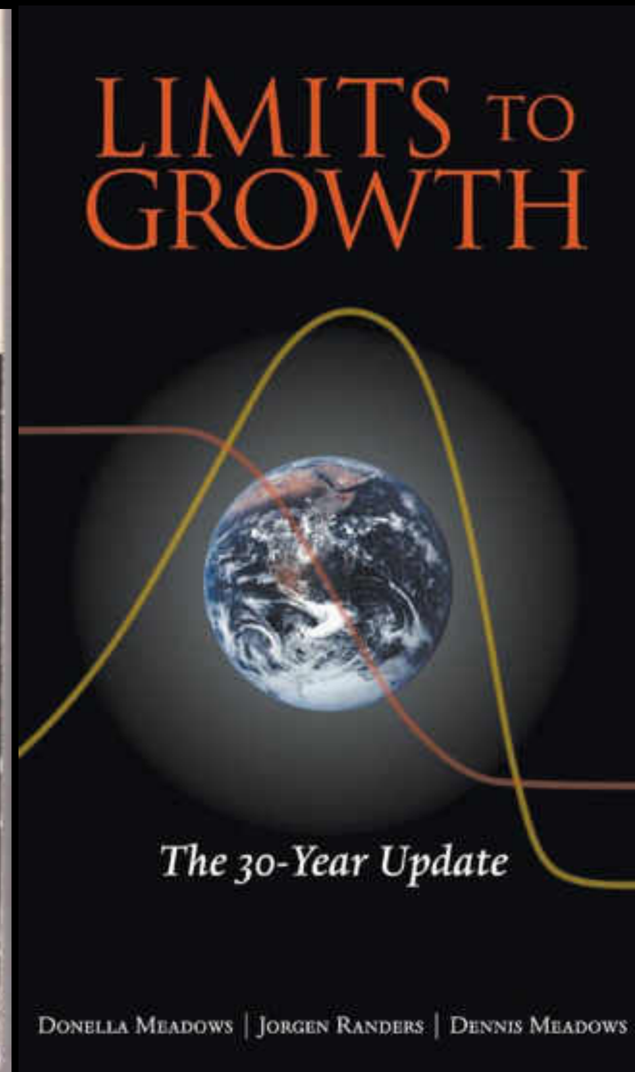
Darrell Kaufman et al. *Scientific Data* **volume 7**, Article number: 201 (2020)

The control over carbon emissions by developed countries is probably not the reason for the globe's survival, but the lack of development in less-developed countries is…. Intergovernmental Panel on Climate Change (IPCC). 2014



https://berkeleyearth.org/dv/10000-years-of-carbon-dioxide/

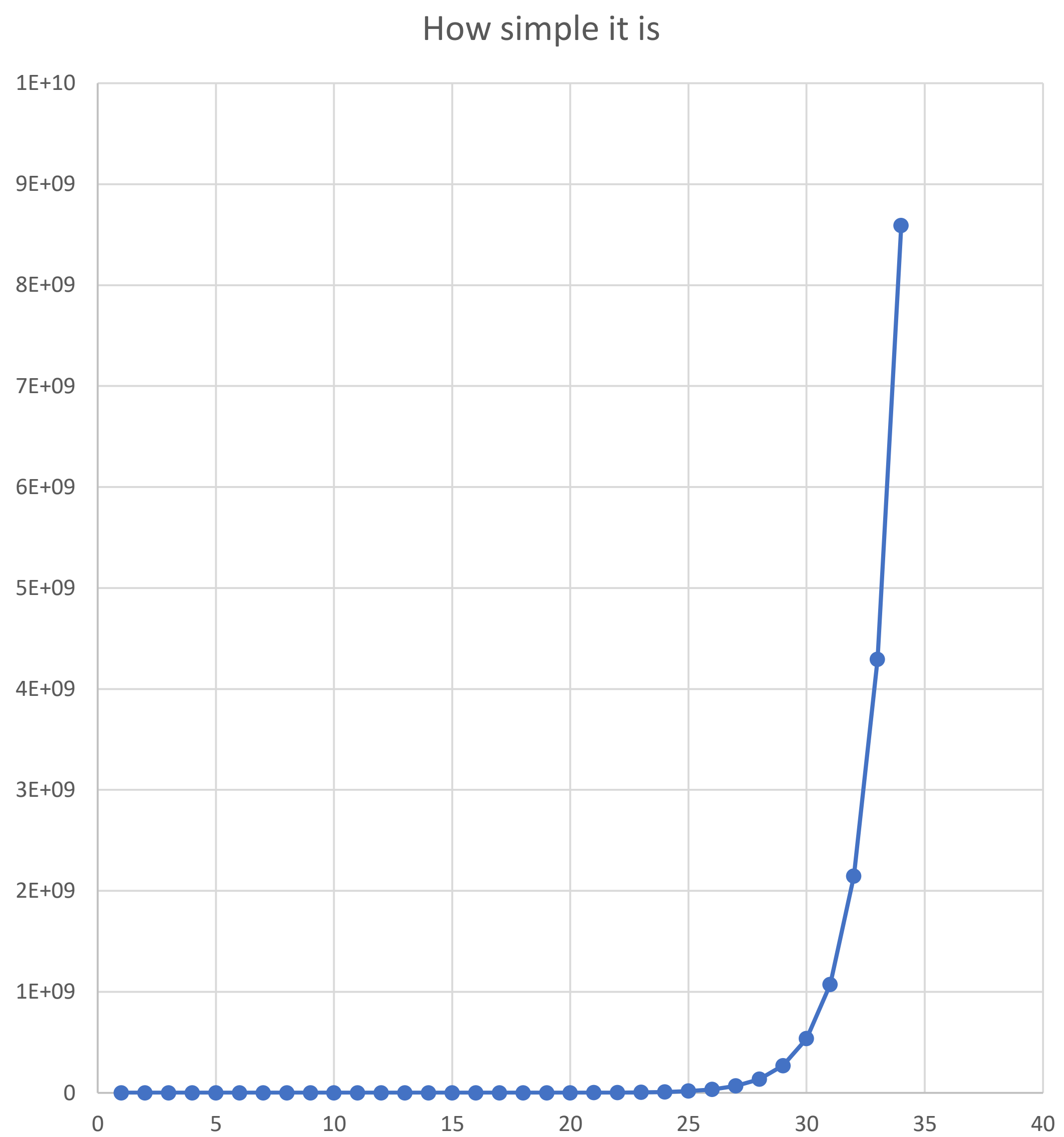

Interdependence
Reflection, heat content
Melting, sea level rise
Biodiversity
…
….
Banking


THE LIMITS TO
growth
Donella H. Meadows
Dennis L. Meadows
Jørgen Randers
William W. Behrens III
A Report for THE CLUB OF ROME'S Project on
Predicament of Mankind
A POTOMAC ASSOCIATES BOOK

THE LIMITS TO GROWTH
The headline-making report on the imminent global disaster facing humanity—and what we can do about it before time runs out. "One of the most important documents of our age!" —Anthony Lewis, The New York Times
DONELLA H. MEADOWS/DENNIS L. MEADOWS
JØRGEN RANDERS/WILLIAM W. BEHRENS III
A POTOMAC ASSOCIATES BOOK
SECOND EDITION
Revised

LIMITS TO GROWTH
The 30-Year Update
Donella Meadows | Jorgen Randers | Dennis Meadows

Science made it possible

- 34 generations to make
- our population

- 34 x 25 = 850 years



Reactions that changed the world

1. $6CO_2 + 6H_2O \dashrightarrow C_6H_{12}O_6 + 6O_2$

2. $H_2 + 3\ H_2 \dashrightarrow 2NH_3$ 220 million tons a year

3. $NH_3 + CO_2 \rightarrow NH_2\text{-}CO\text{-}NH_2 + H_2O$ >180 million tons 2022

4. $CH_4 + O_2 \rightarrow CO_2 + H_2O$

5. $nC_2H_4 \rightarrow -(CH_2)n-$ polyethylene >130 million tons 2022

6. Polymerase chain reaction

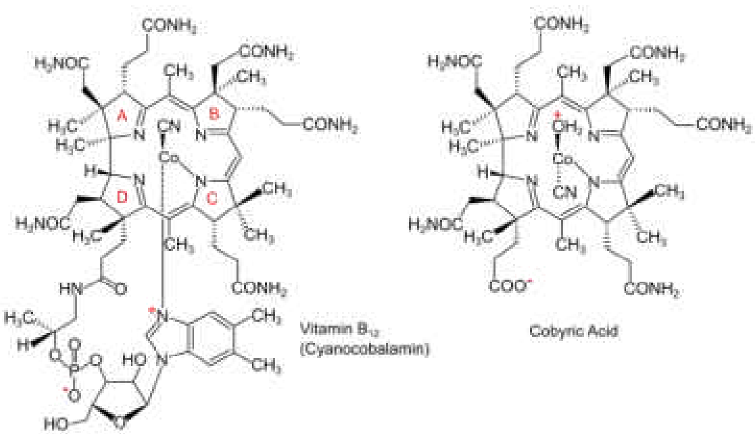
7. Electrochemistry

Molecules that changed the world

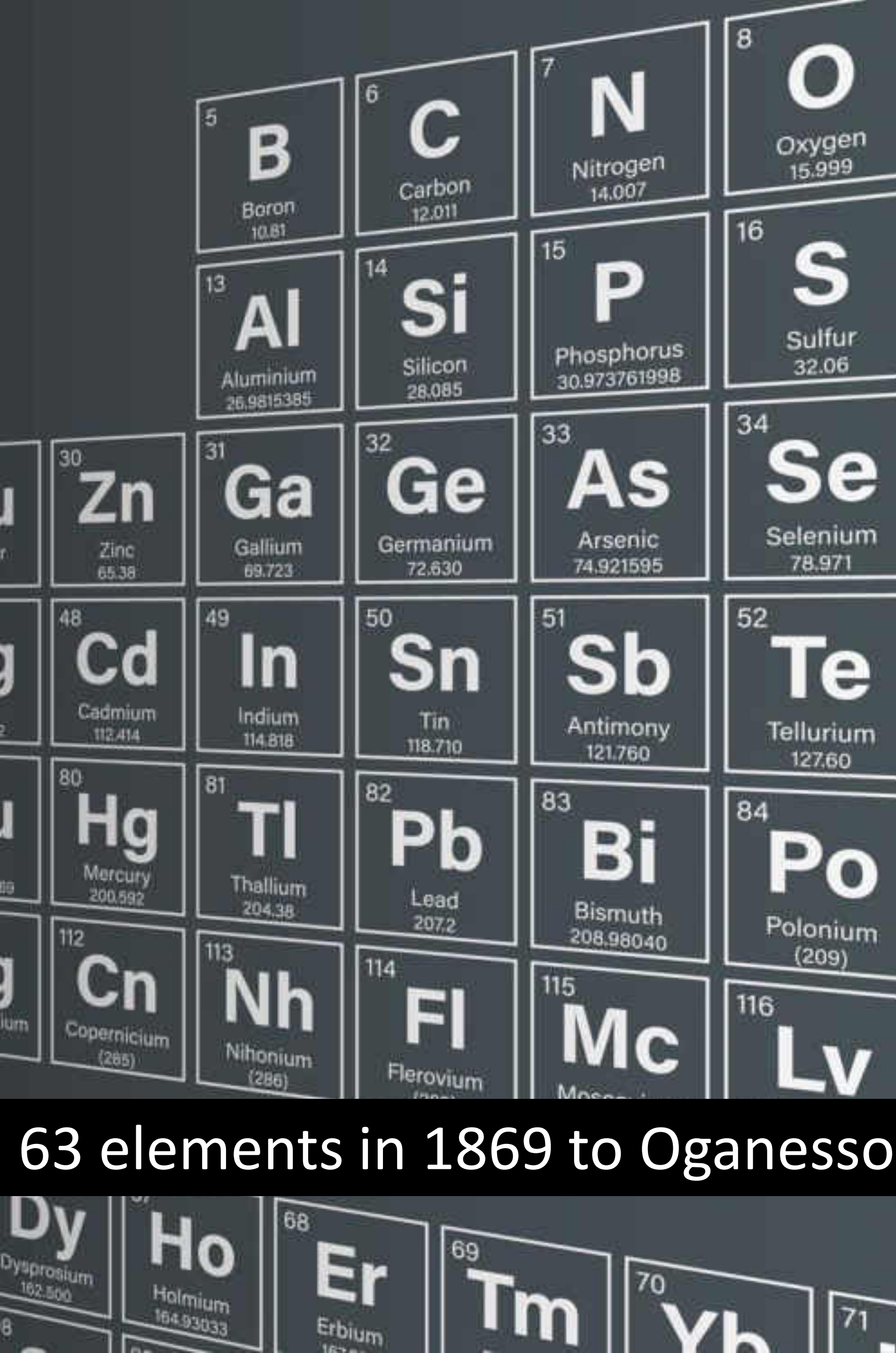
Aspirin, urea, morphine, strychnine, penicillin, vitamin B12, Taxol, and quinine

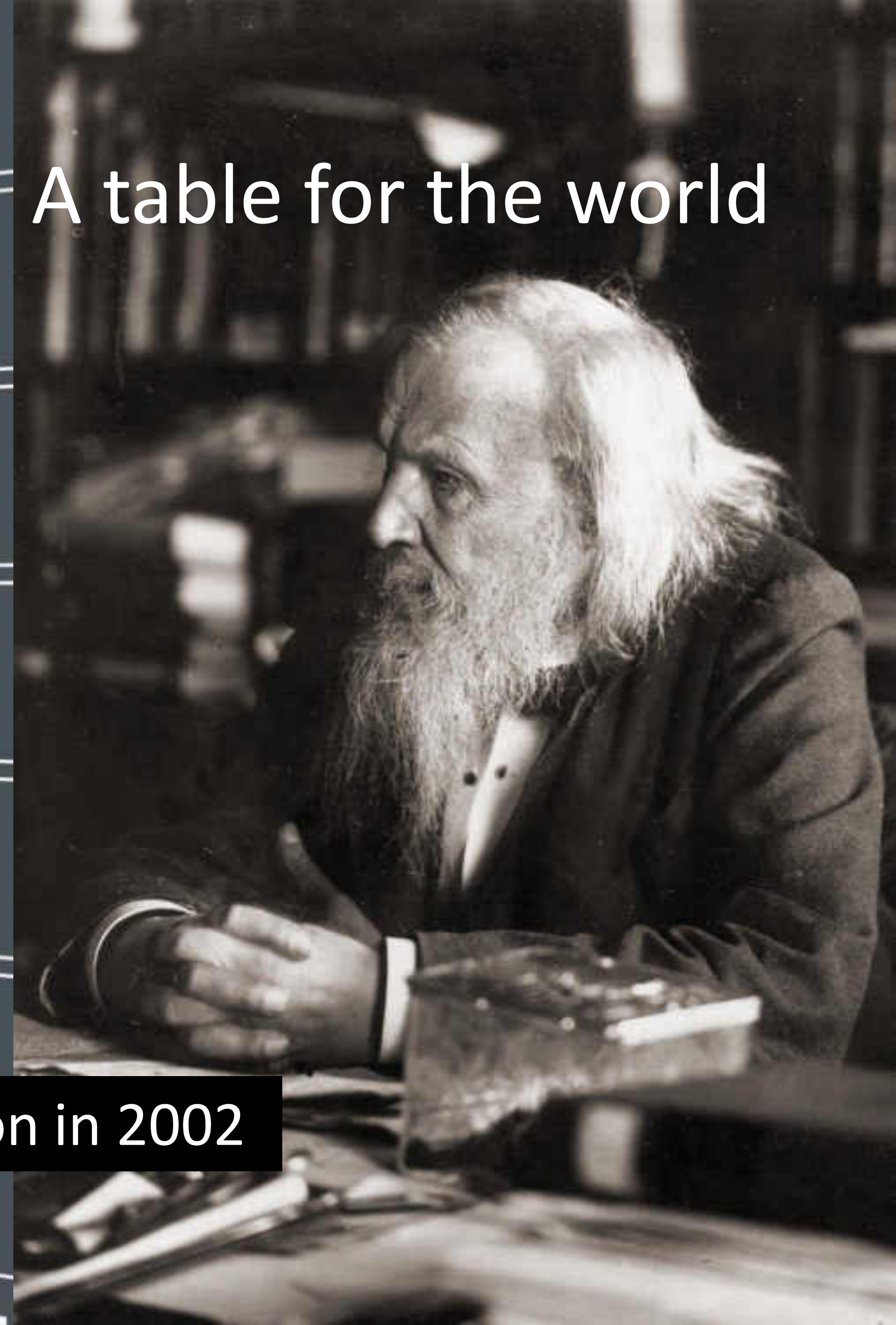
Molecules that destroyed the world

CFCs, DDT, Agent orange - 2,4-dichlorophenoxyacetic acid (2,4-D) and 2,4,5-trichlorophenoxyacetic acid (2,4,5-T), endosulfan, thalidomide,…



A table for the world





63 elements in 1869 to Oganesson in 2002

Molecules – Diseases and their cure

Reprinted from Science, November 25, 1949, Vol. 110, No. 2865, pages 543–548.

Sickle Cell Anemia, a Molecular Disease[1]

Linus Pauling, Harvey A. Itano,[2] S. J. Singer,[3] and Ibert C. Wells[2]

Gates and Crellin Laboratories of Chemistry,
California Institute of Technology, Pasadena, California[4]

THE ERYTHROCYTES of certain individuals possess the capacity to undergo reversible changes in shape in response to changes in the partial pressure of oxygen. When the oxygen pressure is lowered, these cells change their forms from the normal biconcave disk to crescent, holly wreath, and other forms. This process is known as sickling. About 8 percent of American Negroes possess this characteristic; usually they exhibit no pathological consequences ascribable to it. These people are said to have sicklemia, or sickle cell trait. However, about 1 in 40 (4) of these individuals whose cells are capable of sickling suffer from a severe chronic anemia resulting from excessive destruction of their erythrocytes; the term sickle cell anemia is applied to their condition.

The main observable difference between the erythrocytes of sickle cell trait and sickle cell anemia has been that a considerably greater reduction in the partial pressure of oxygen is required for a major fraction of the trait cells to sickle than for the anemia cells (11). Tests in vivo have demonstrated that between 30 and 60 percent of the erythrocytes in the venous circulation of sickle cell anemic individuals, but less than 1 percent of those in the venous circulation of sicklemic individuals, are normally sickled. Experiments in vitro indicate that under sufficiently low oxygen pressure, however, all the cells of both types assume the sickled form.

The evidence available at the time that our investigation was begun indicated that the process of sickling might be intimately associated with the state and the nature of the hemoglobin within the erythrocyte. Sickle cell erythrocytes in which the hemoglobin is combined with oxygen or carbon monoxide have the biconcave disk contour and are indistinguishable in that form from normal erythrocytes. In this condition they are termed promeniscocytes. The hemoglobin appears to be uniformly distributed and randomly oriented within normal cells and promeniscocytes, and no birefringence is observed. Both types of cells are very flexible. If the oxygen or carbon monoxide is removed, however, transforming the hemoglobin to the uncombined state, the promeniscocytes undergo sickling. The hemoglobin within the sickled cells appears to aggregate into one or more foci, and the cell membranes collapse. The cells become birefringent (11) and quite rigid. The addition of oxygen or carbon monoxide to these cells reverses these phenomena. Thus the physical effects just described depend on the state of combination of the hemoglobin, and only secondarily, if at all, on the cell membrane. This conclusion is supported by the observation that sickled cells when lysed with water produce discoidal, rather than sickle-shaped, ghosts (10).

It was decided, therefore, to examine the physical and chemical properties of the hemoglobins of individuals with sicklemia and sickle cell anemia, and to compare them with the hemoglobin of normal individuals to determine whether any significant differences might be observed.

Experimental Methods

The experimental work reported in this paper deals largely with an electrophoretic study of these hemoglobins. In the first phase of the investigation, which concerned the comparison of normal and sickle cell anemia hemoglobins, three types of experiments were performed: 1) with carbonmonoxyhemoglobins; 2) with uncombined ferrohemoglobins in the presence of dithionite ion, to prevent oxidation to methemoglobins; and 3) with carbonmonoxyhemoglobins in the presence of dithionite ion. The experiments of type 3 were performed and compared with those of type 1 in order to ascertain whether the dithionite ion itself causes any specific electrophoretic effect.

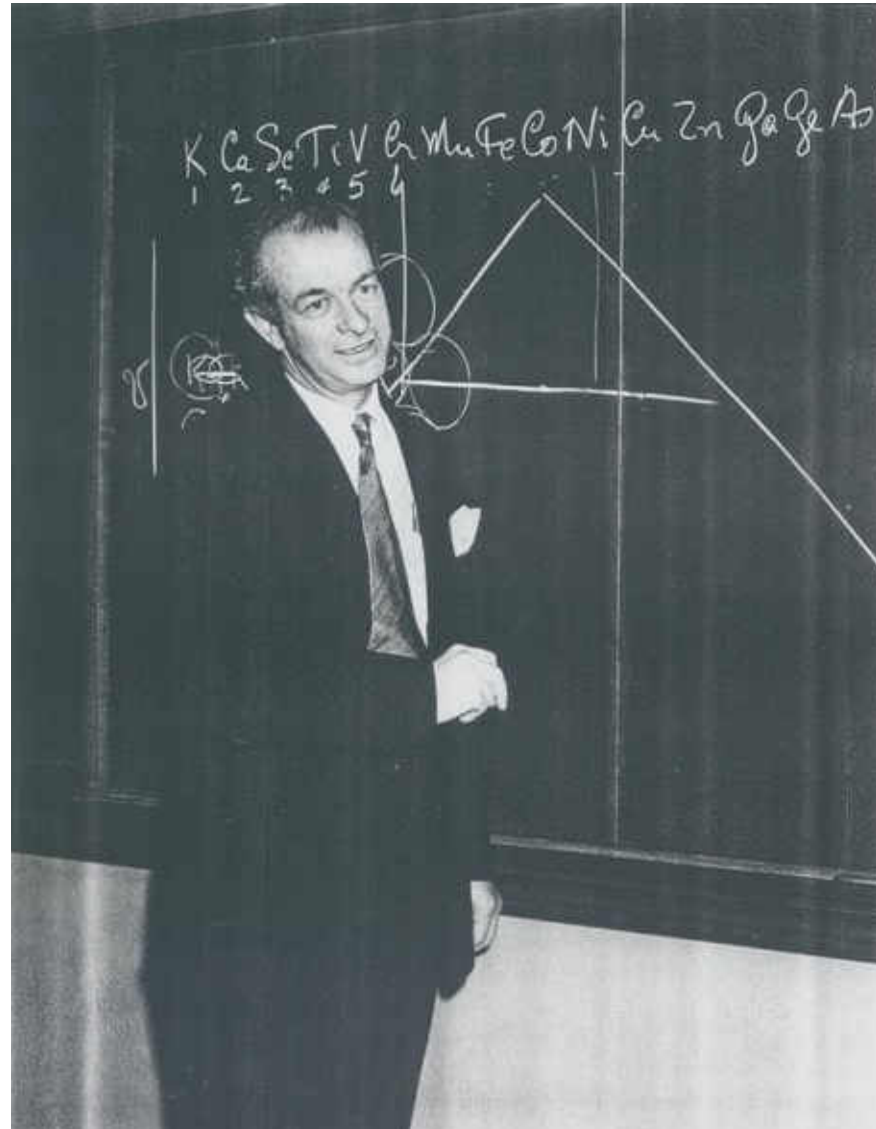
Samples of blood were obtained from sickle cell anemic individuals who had not been transfused within three months prior to the time of sampling. Stroma-free concentrated solutions of human adult hemoglobin were prepared by the method used by Drabkin (5). These solutions were diluted just before use with the

[1] This research was carried out with the aid of a grant from the United States Public Health Service. The authors are grateful to Professor Ray D. Owen, of the Biology Division of this Institute, for his helpful suggestions. We are indebted to Dr. Edward R. Evans, of Pasadena, Dr. Travis Winsor, of Los Angeles, and Dr. G. E. Burch, of the Tulane University School of Medicine, New Orleans, for their aid in obtaining the blood used in these experiments.

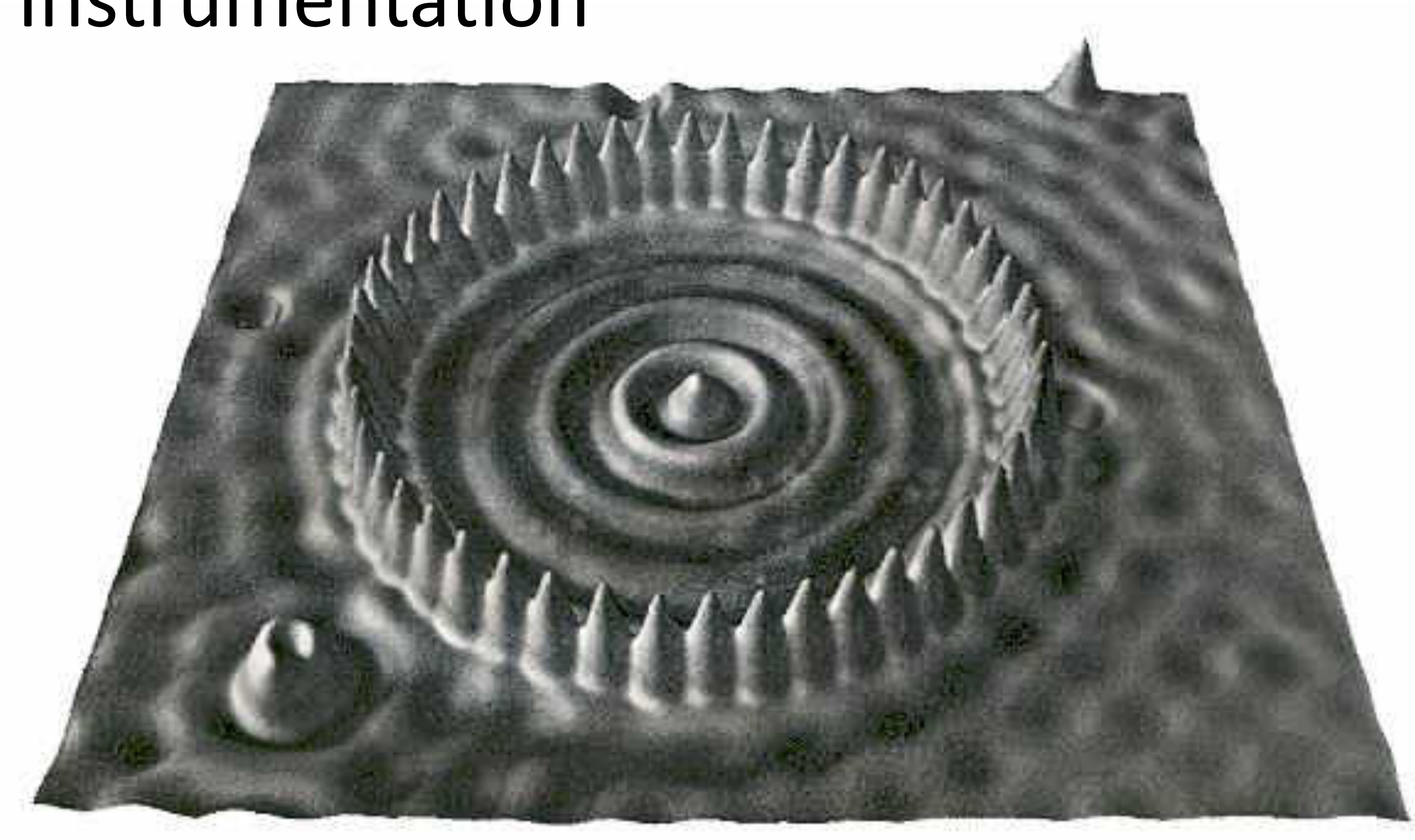
[2] U. S. Public Health Service postdoctoral fellow of the National Institutes of Health.

[3] Postdoctoral fellow of the Division of Medical Sciences of the National Research Council.

[4] Contribution No. 1333.



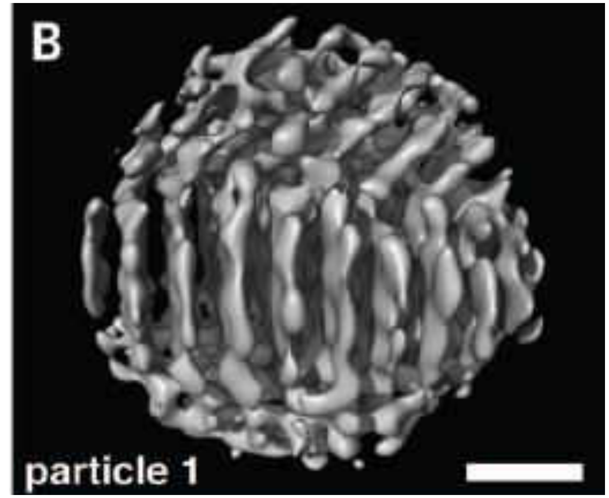
Instrumentation



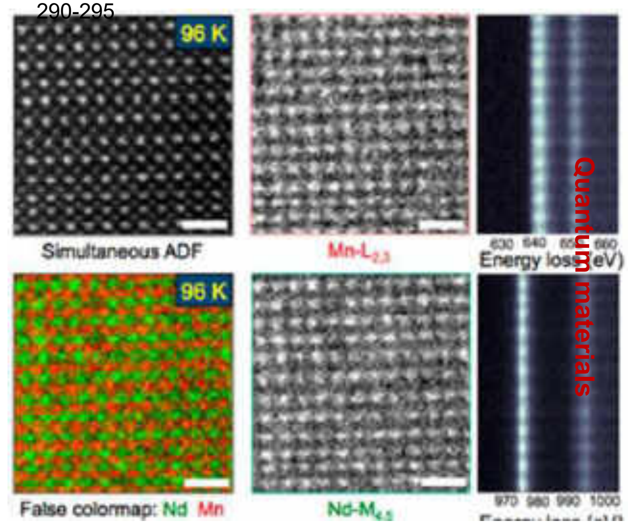
STM image of a "quantum corral" (courtesy IBM Research Division).

D. W. Eigler, et. Al. Science, 262(5131), 218-220.

Seeing atoms, molecules and assemblies



3D Structure of Individual Nanocrystals in Solution by Electron Microscopy. Park, J. et al., *Science* **2015,** *349,* 290-295

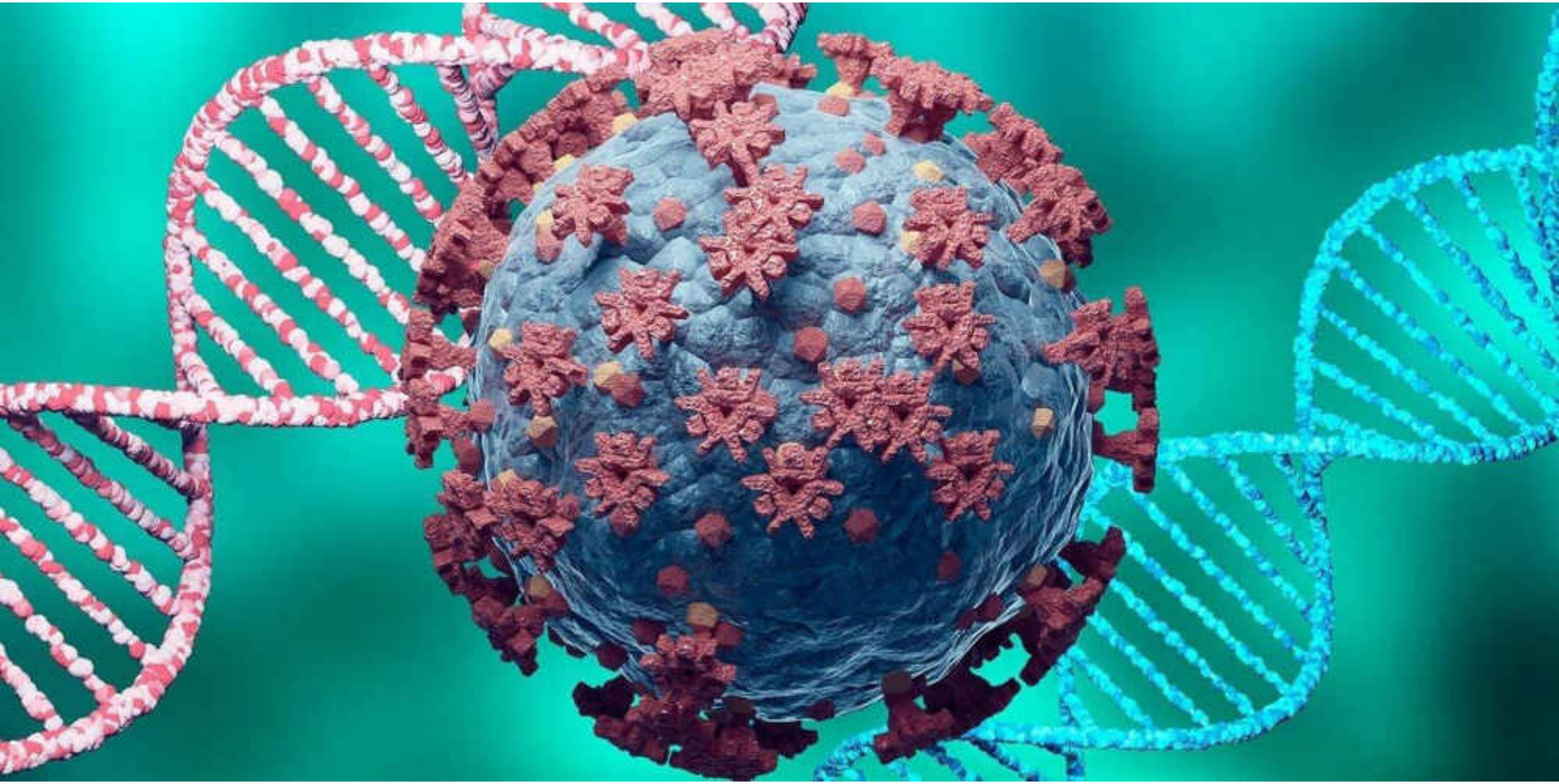


Baek, D. J. et al., *Microsc.Microanal*. **2018**, *24*, 454−455
Nature and evolution of incommensurate charge order in manganites visualized with cryogenic scanning transmission electron microscopy. Baggari, I. E. et al., *Proc. Natl. Acad. Sci*. **2018**, *115*, 1445−1450.

https://www............

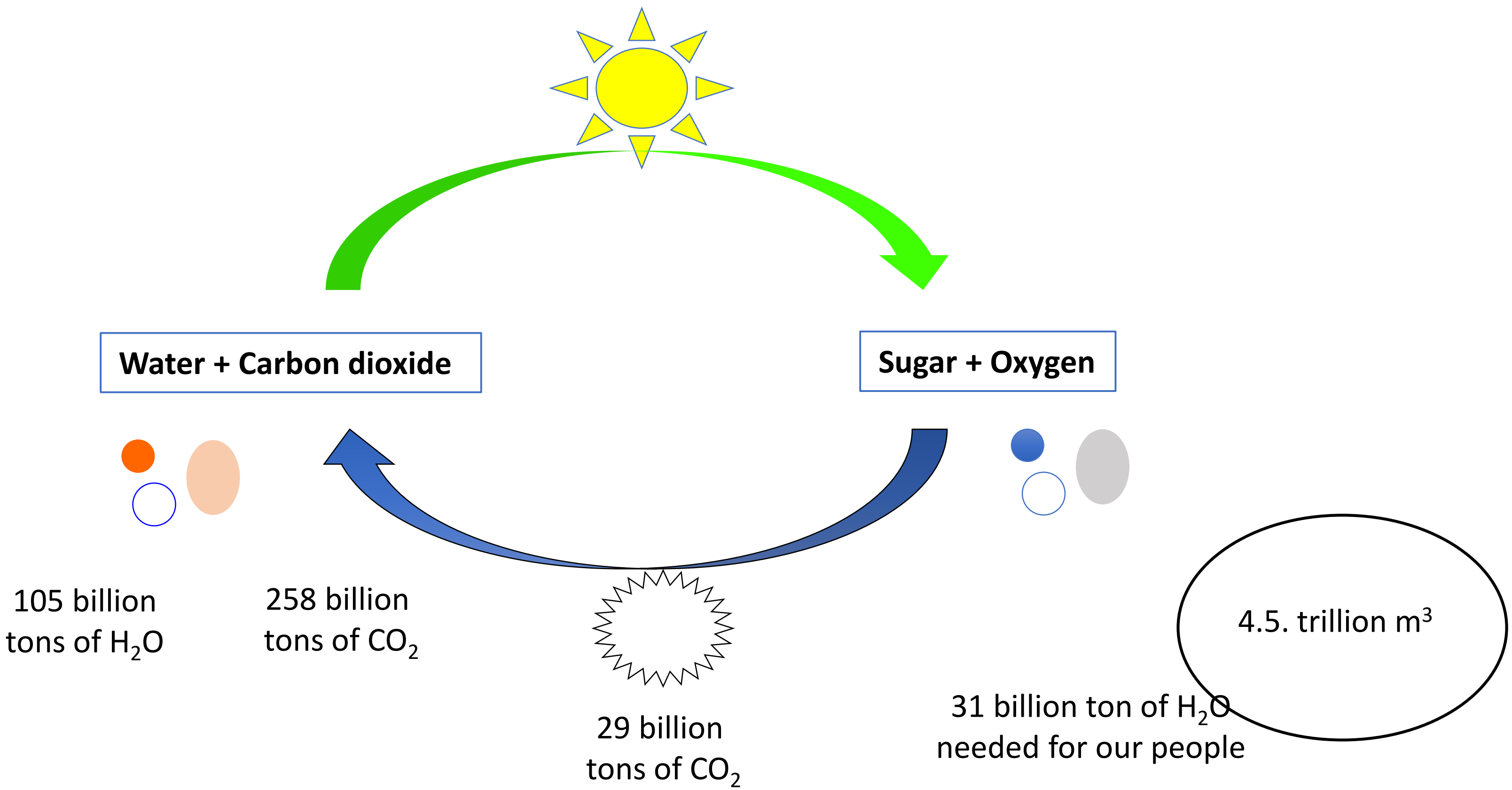
From https://www.simplilearn.com/what-is-internet-article

Nature, engineering, life….



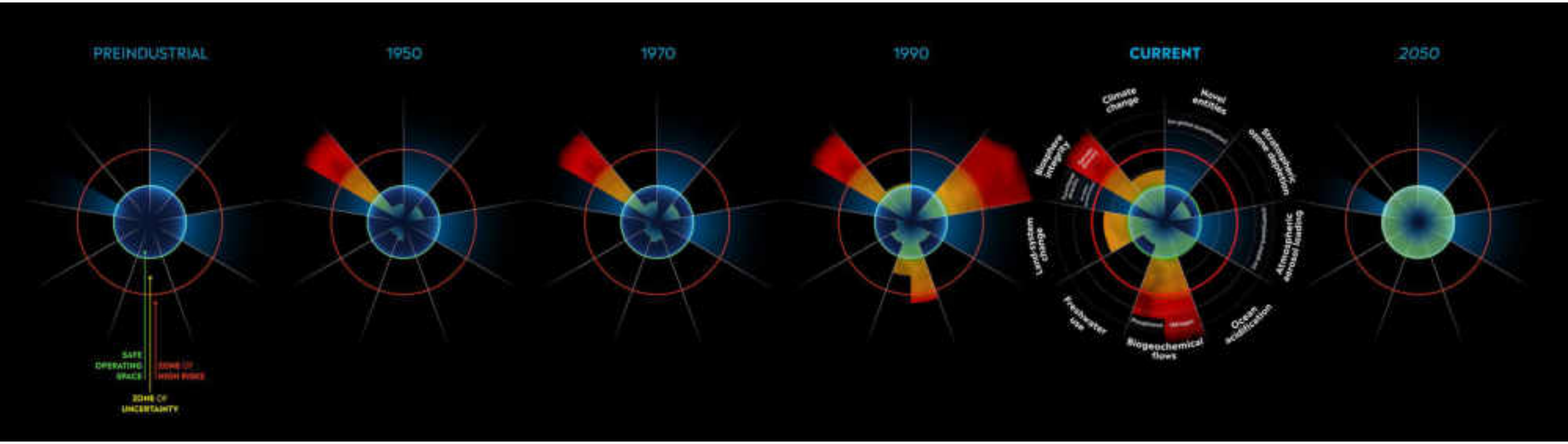
From WHO

We opened the cycle



Our restriction – confined space

Planetary boundaries



https://globaia.org/planetary-boundaries

Biological complexity is built with just a few elements

https://blog.gale.com/celebrating-the-periodic-table/

We developed environmentally friendly water positive nanoscale materials for affordable, sustainable and rapid removal of arse
from drinking water.

There are over 1700 community installations across the country, serving 1.3 million people with arsenic and iron-free water eve

Biopolymer-reinforced synthetic granular nanocomposites for affordable point-of-use water purification

Mohan Udhaya Sankar[1], Sahaja Aigal[1], Shihabudheen M. Maliyekkal[1], Amrita Chaudhary, Anshup, Avula Anil Kumar, Kamalesh Chaudhari, and Thalappil Pradeep[2]

Unit of Nanoscience and Thematic Unit of Ex

Madras, Chennai 600 036, India

Edited by Eric Hoek, University of California,

(received for review November 21, 2012)

Creation of affordable materials for cons
water is one of the most promising way
drinking water for all. Combining the
composites to scavenge toxic species
other contaminants along with the ab
affordable, all-inclusive drinking water
without electricity. The critical proble
synthesis of stable materials that can
uously in the presence of complex s
drinking water that deposit and caus
surfaces. Here we show that such con
be synthesized in a simple and effective
out the use of electrical power. The na
sand-like properties, such as higher shea
forms. These materials have been used
water purifier to deliver clean drinking
ily. The ability to prepare nanostructu
ambient temperature has wide releva
water purification.

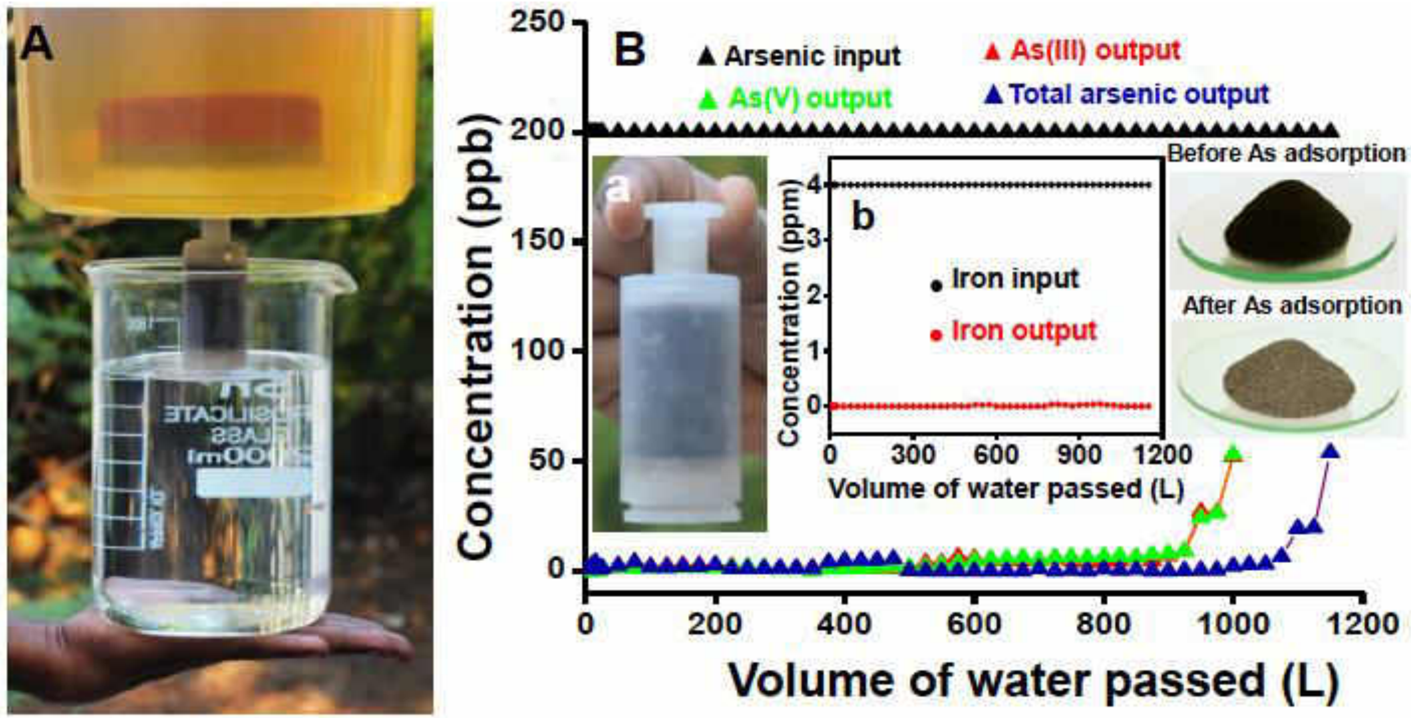
hybrid | green | appropriate technology | frugal science | developing world

vailable; and (*c*) continued retention
matrix is difficult.
ate a unique family of nanocrystalline
n granular composite materials pre-
ature through an aqueous route. The
mposition is attributed to abundant -O-
on chitosan, which help in the crys-
oxide and also ensure strong covalent
surface to the matrix. X-ray photo-
) confirms that the composition is rich
ps. Using hyperspectral imaging, the
aching in the water was confirmed.
to reactivate the silver nanoparticle
al antimicrobial activity in drinking
osites have been developed that can
its in water. We demonstrate an af-
device based on such composites de-
nd undergoing field trials in India, as
spread eradication of the waterborne

Results and Discussion

M. Udhaya Sankar, et. al. *Proc. Natl. Acad. Sci.,* 110 (2013) 8459-8464.

Range of materials, their affordability and safety



Safety of spent media, TCLP

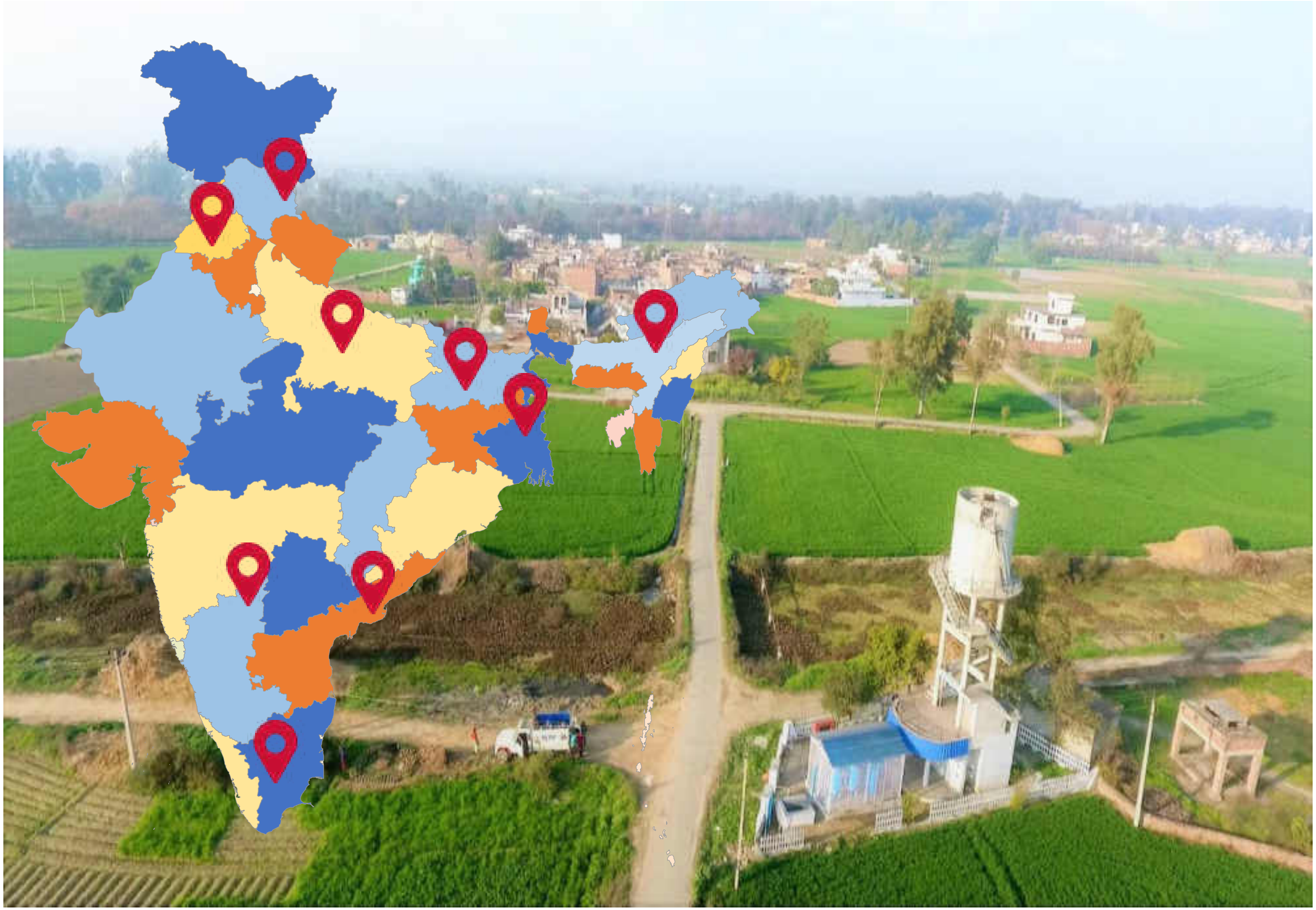
A. Anil Kumar, et. al. *Adv. Mater.*, 29 (2016) 1604260.

Clean water for everyone



ACS Sustainable Chemistry & Engineering Editorial, December 2016

Expanding the reach



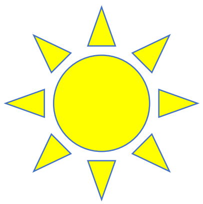
Where can we invest our time and effort?

CO_2 → C1 → Cn → CO_2

Image from: https://delta2020.com/blog/203-our-shrinking-world

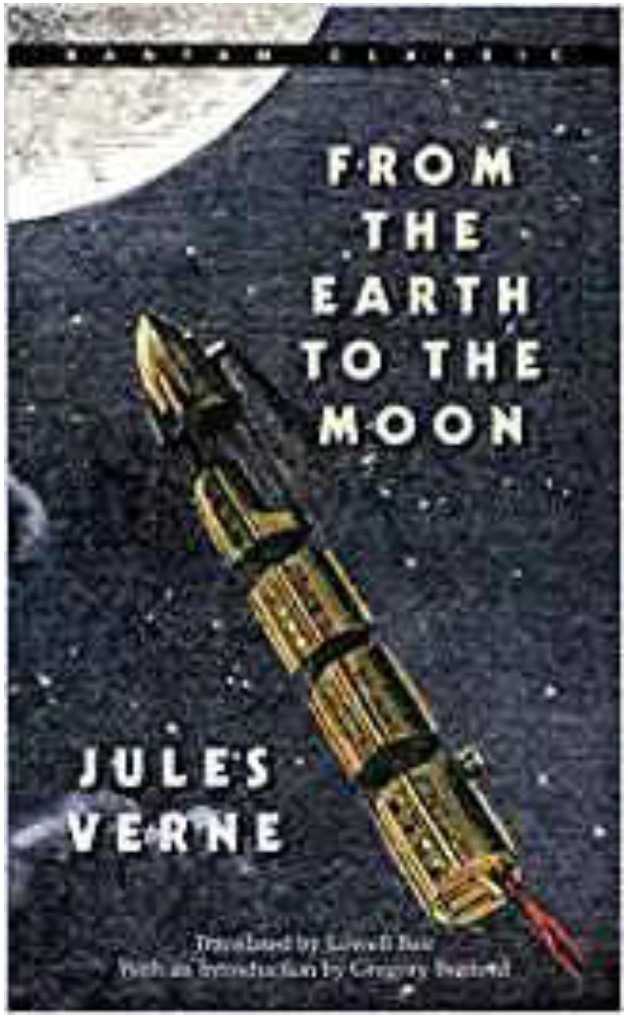
Our dreams become reality with materials

Energy



H_2O

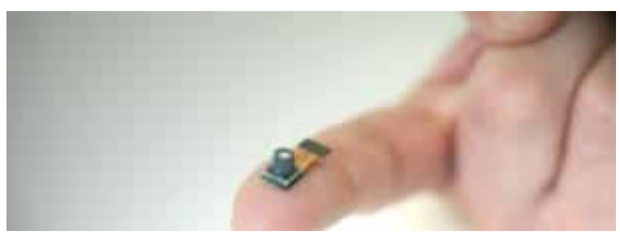
H_2O



Clean water

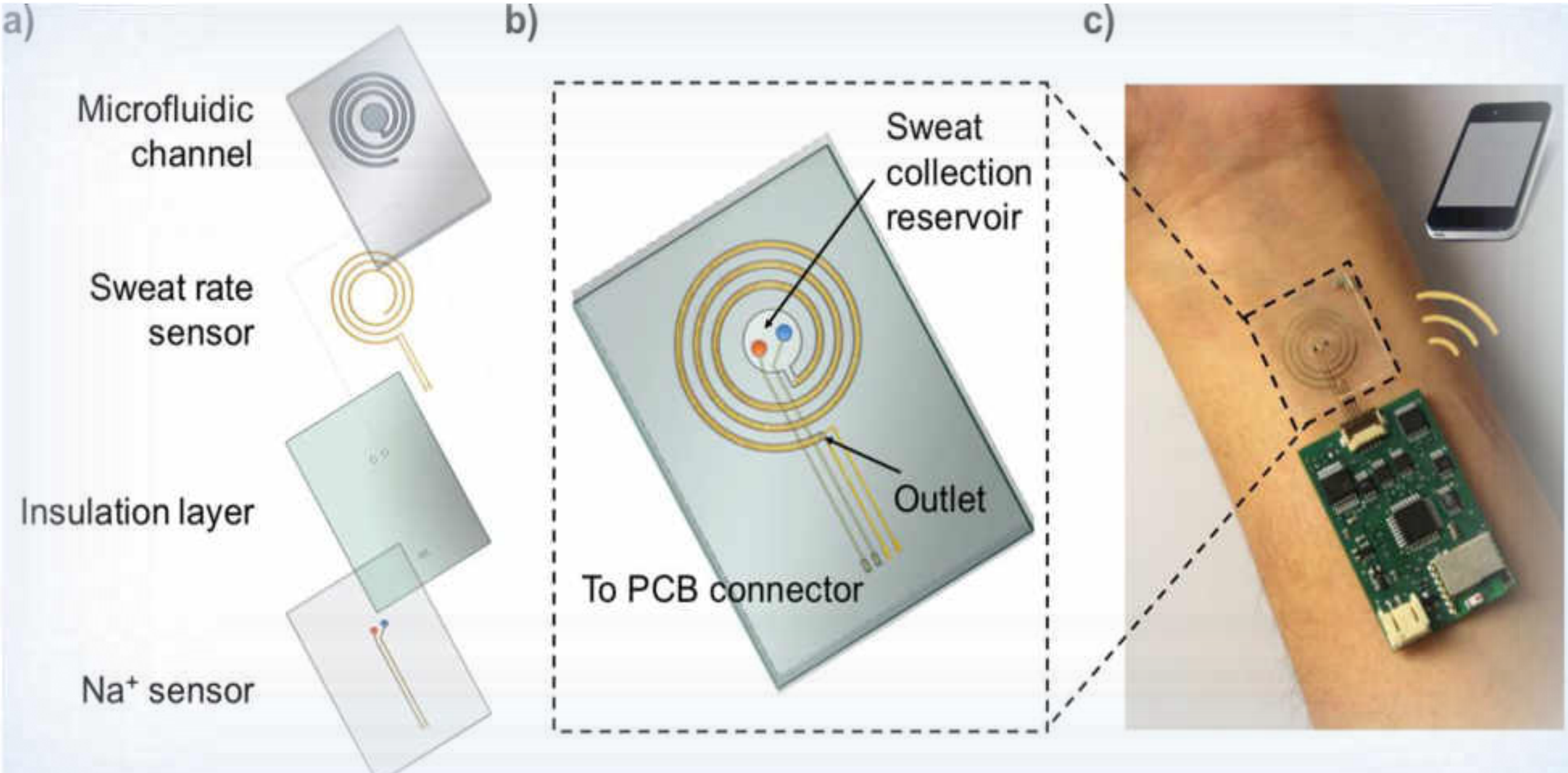
Affordable, inclusive, sustainable and contextual excellence

Sensors and new opportunities



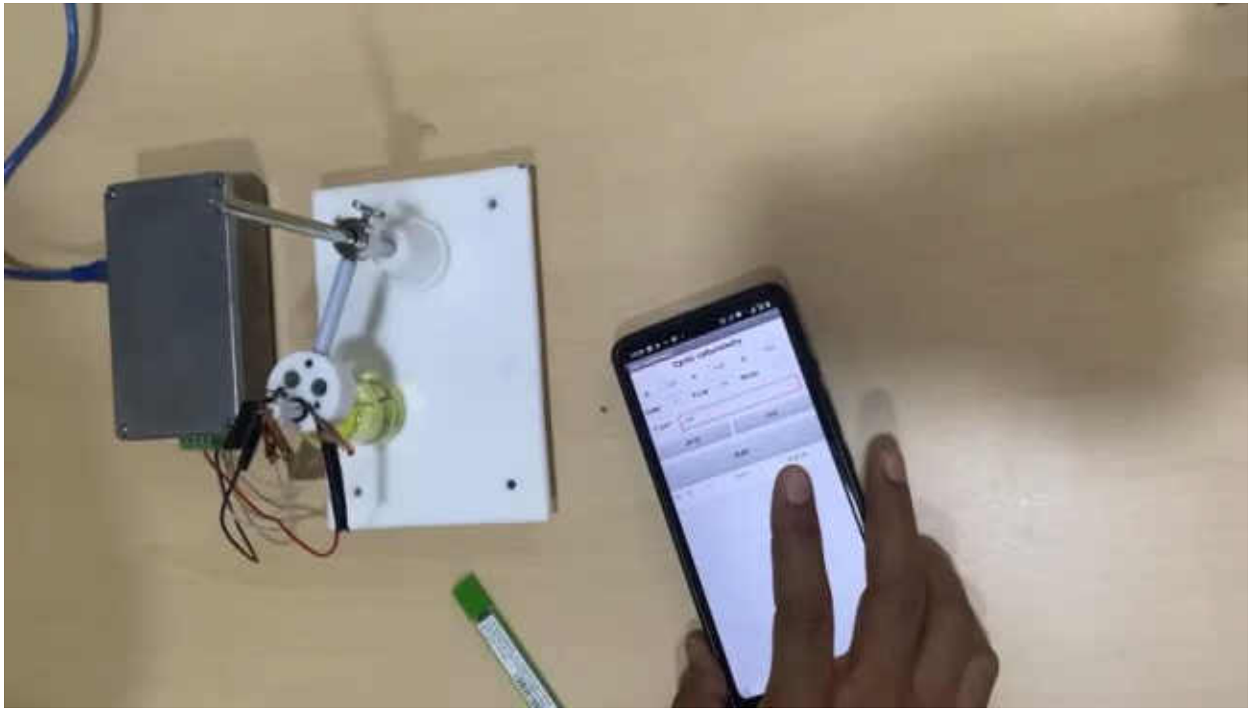
Water quality measurement – In the pipeline

Health



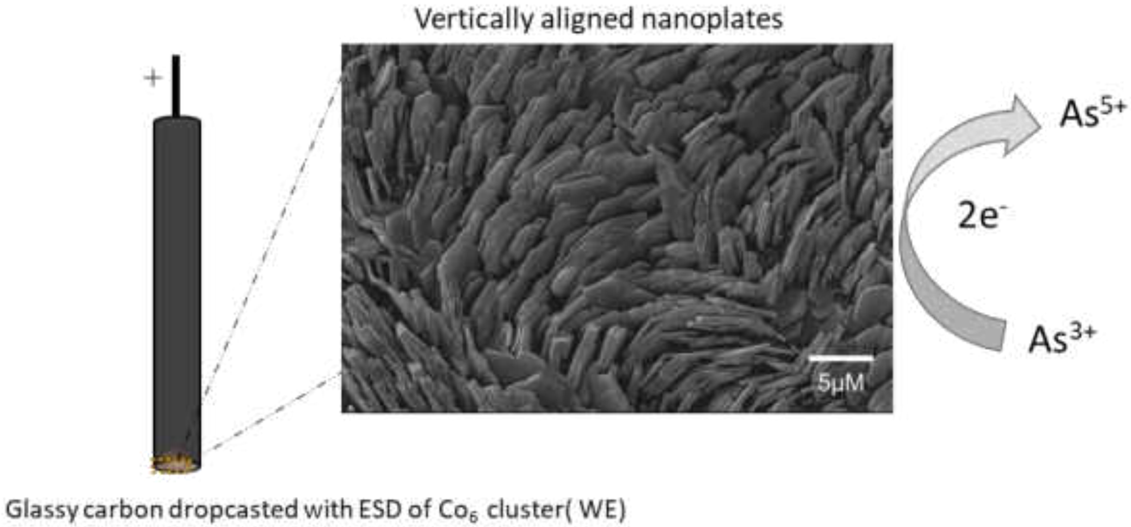
H.Y.Y. Nyein, et. Al., ACS Sens. 2018, 3, 944−952

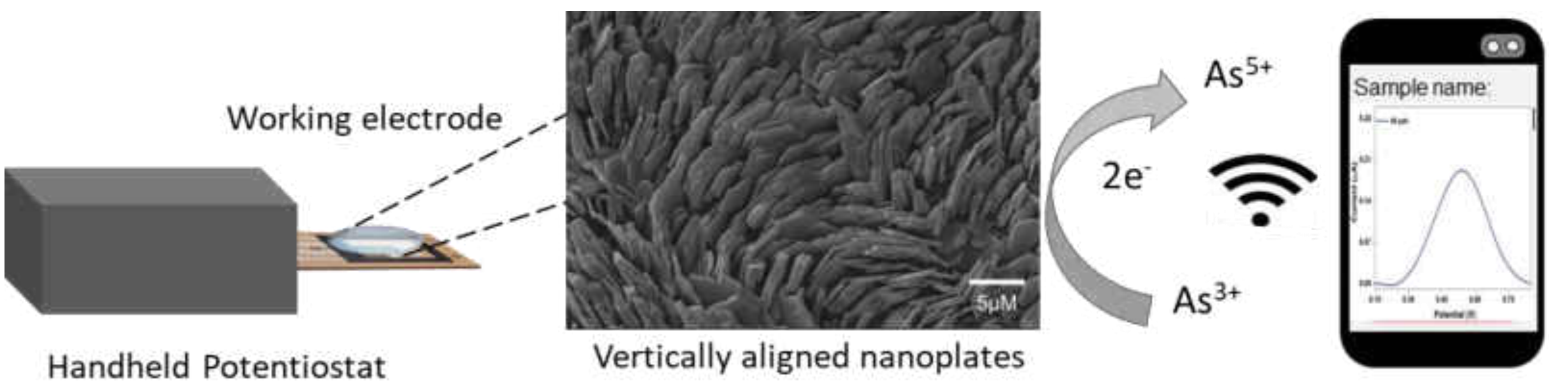
Arsenic detection at 1 ppb in the field!



Sourav Kanti Jana

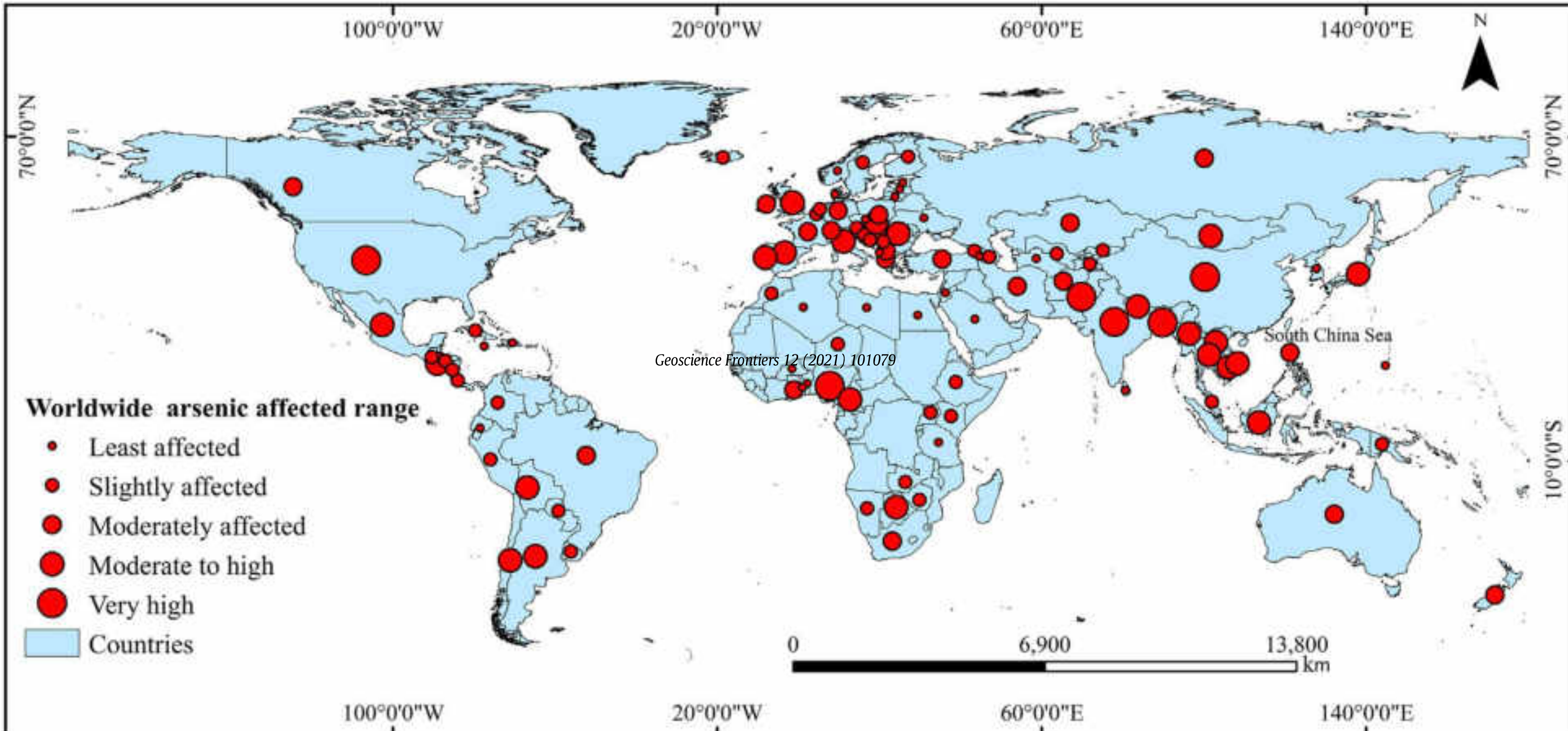
Working electrode





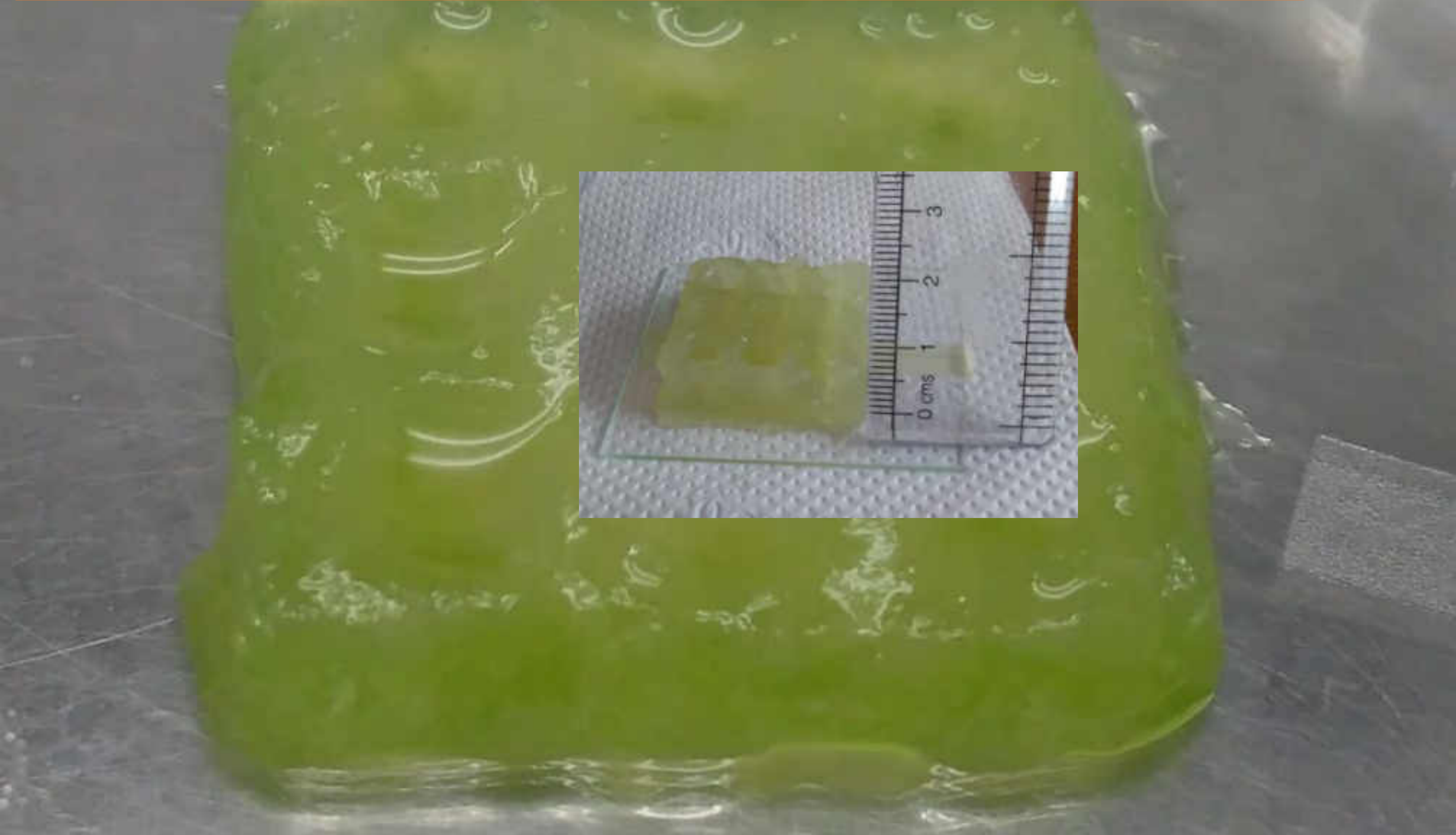
Anagha Jose et al. 2023

Arsenic poisoning across the world



E. Shaji, M. Santosh, K. V. Sarath, Pranav Prakash, V. Deepch and B. V. Divya, Geoscience Frontiers, 12 (2021) 101079.

Food



Author’s laboratory

[redacted]

Water team at IIT: A. Sreekumaran Nair, Anshup, M. Udhaya Sankar, Amrita Chaudhary, Renjis T. Tom, T. S. Sreeprasad, Udayabhaskararao Thumu, M. S. Bootharaju, K. R. Krishnadas, Kalamesh Chaudhari, Soujit Sengupta, Depanjan Sarkar, Avijit Baidya, Swathy Jakka Ravindran, Abhijit Nag, S. Vidhya, Biswajit Mondal, Krishnan Swaminathan, Azhardin Gnayee, Sudhakar Chennu, A. Suganya, Rabiul Islam, Sritama Mukherjee, Tanvi Gupte, Jenifer Shantha Kumar, A. Anil Kumar, Ankit Nagar, Ramesh Kumar Soni, Tanmayaa Nayak, Sonali Seth, Shihabudheen M. Maliyekkal, G. Velmurugan, Wakeel Ahmed Dar, Ganapati Natarajan, N. Pugazhenthiran, A. Leelavathi, Sahaja Aigal, S.Gayathri, Bibhuti Bhusan Rath, Ananthu Mahendranath, Harsh Dave, Erik Mobegi, Egor Moses, Hemanta R. Naik, Sourav Kanti Jana,...

Avula Anil Kumar, Chennu Sudhakar, Sritama Mukherjee, Anshup, and Mohan Udhaya Sankar

Funding: Department of Science and Technology, Government of India

Start-ups and partners:

PhD Theses: Bindhu Varughese, M. R. Resmi, M. Venkataramanan, N. Sandhyarani, R. Selvan, A. Sreekumaran Nair, M. J. Rosemary, Renjis T. Tom, C. Subramaniam, Jobin Cyriac, V. R. Rajeev Kumar, D. M. David Jeba Singh, Akshaya Kumar Samal, E. S. Shibu, M. A. Habeeb Muhammed, P. R. Sajanlal, T. S. Sreeprasad, J. Purushothaman, T. Udayabhaskararao, M. S. Bootharaju, Soumabha Bag, Robin John, Kamalesh Chaudhari, Ammu Mathew, Indranath Chakraborty, Radha Gobinda Bhuin, Ananya Baksi, Amitava Srimony, Anirban Som, Rabin Rajan Methikkalam, K. R. Krishnadas, Soujit Sengupta, Depanjan Sarkar, Atanu Ghosh, Rahul Narayanan, Avijit Baidya, Shridevi Bhat, Papri Chakraborty, Swathy Jakka Ravindran, C. K. Manju, Abhijit Nag, S. Vidhya, Jyoti Sarita Mohanty, Debasmita Ghosh, Jyotirmoy Ghosh, Md. Bodiuzzaman, Biswajit Mondal, Tripti Ahuja, Esma Khatun, Krishnan Swaminathan, K. S. Sugi, Amrita Chakraborty, Sudhakar Chennu, Sritama Mukherjee, Madhuri Jash, Sandeep Bose, Md. Rabiul Islam, Pallab Basuri, Mohd Azhardin Ganayee, Tanvi Gupte

>25 Post-doctoral fellows, >130 masters students and visitors

Indian Institute of Technology Madras

Bhaskar Ramamurthi/V. Kamakoti

Thank you all

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